

# Visual Query and Analysis Tool of the Object-Relational GIS Framework

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## ABSTRACT

Geographic Information Systems (GISs) have become an essential tool for efficient handling of our natural and artificial environment. The most important activities in a GIS are querying and spatial analysis of georeferenced data providing decision making and problem solving support. Traditional database query languages and tools are inappropriate for GIS purpose, because of their inability to address spatial properties of the real world entities. This paper presents a spatial query and analysis tool with the strong visual context, called GeoQA. It has been developed as an integral component of the GiniNT, object-oriented GIS framework for GIS applications development. GeoQA provides effective, interactive but user-friendly and ease-of-use mechanisms for performing spatial and non-spatial queries, as well as, spatial, thematic and statistic analysis in specific GIS applications developed on the top of GiniNT.

## 1. INTRODUCTION

During the last decades, the number of computer systems and scientific applications that are able to manage, represent and evaluate two- or three-dimensional spatial data has steadily increased. The major problems and challenges in the modern life have a significant geographic dimension, so the best-known and most important application area for spatial data management is Geographic Information System (GIS). GIS is a computer-based system that is able to store, manage, analyse and visualise a great deal of geographic information. These abilities make GIS valuable to a wide range of public and private enterprises for mapping and analysing objects, explaining events, predicting outcomes and

planning strategies. The most important activities in a GIS are information retrieval and spatial analysis of georeferenced data, as a support for decision making and problem solving [1]. These activities are not new, but GIS performs these tasks better and faster than old manual methods. Integration between GIS and spatial analysis takes the form of a query language, whose primitive elements represent the fundamental operations of spatial analysis. Spatial querying and analysis are helpful in a number of various situations where "better" information leads to better decisions.

Scientists and engineers using GIS need a query and analysis tool with powerful spatial selection methods and analysis capabilities, but visual, user-friendly and ease-of-use, to infer spatial information in a manner similar to a human expert. Traditional SQL-like database query languages are inappropriate for GIS applications [2]. They are not able to provide additional functionality to address spatial properties of real world entities in specific multidimensional space. These languages possess complex textual syntax, as well as, textual input and output, which is unsatisfactory from GIS point of view. Therefore, the spatial query and analysis tool must be provided as a functional extension of a standard query language that enables handling of various spatial concepts in query definition and processing, as well as, performing various spatial analysis functions.

This paper presents the spatial query and analysis tool for GIS with strong visual context, called GeoQA. GeoQA enables formulation and processing of spatial, non-spatial and combined queries, graphical presentation of query results and efficient spatial analysis of specific geographic situation.

## 2. GINIANT: A GIS FRAMEWORK

GeoQA spatial query and analysis tool is implemented as an integral part of the GiniNT system [7]. GiniNT is an object-oriented GIS framework for the development of scaleable end-user GIS applications. It is based on an object-oriented (OO) data model and OO application development methodology, supported by the specific software components and tools and extensible class library. The GiniNT data model and OO environment defined by GiniNT framework are used at the application level, while the underlying spatial database is actually stored, organised and maintained by the RDBMS. The relational implementation level is completely transparent to the user by existence of GiniNT

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intermediary software components that automatically perform mapping between two data models. Therefore, GiniNT is an object-relational development environment that provides the basic GIS functionality found in commercial GIS software, with the additional advantages of flexibility and the ease of development of end-user applications. The architecture of GiniNT is shown in Figure 1.

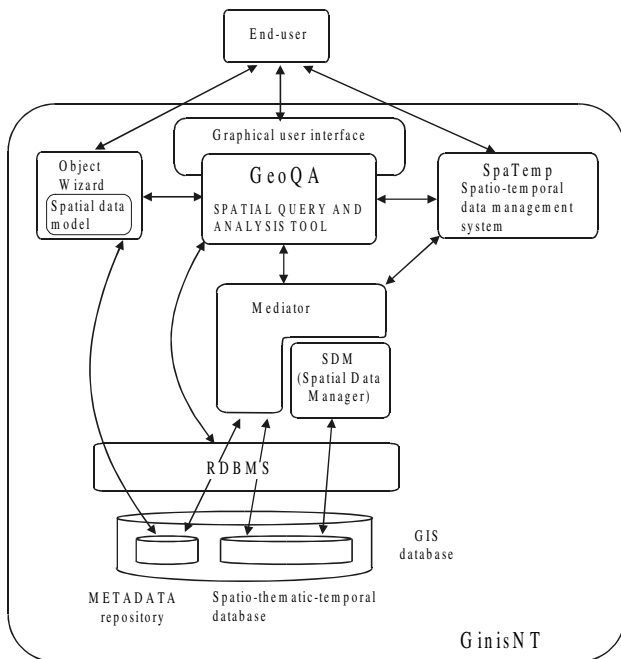


Figure 1. GiniNT and GeoQA.

*Object Wizard* is an OO CASE tool that implements GiniNT OO methodology by supporting schema definition [7]. *Object Wizard* supporting the modelling phase, performs automatic mapping of the OO model of an application into the relational schema, creates all the necessary structures in the relational database and also stores the definition of the application in the metadata repository. User defined schemas are stored in the Metadata Repository (MDR). The existence of MDR deliberates the user from the burden of memorising database schemas and corresponding access mechanisms. *Object Wizard* stores the definition of classes and corresponding information about tables in MDR when the classes are mapped into the relational data model. MDR also supports schema evolution. Users can easily change schemas without even having to change the underlying code manually.

*Mediator* is a GiniNT component that interfaces between the end-user, metadata repository and the database [10]. *Mediator* manages attribute data (alphanumeric and other descriptive data), while spatial data is handled, accessed and indexed exclusively by the *Spatial Data Manager* (SDM). *Mediator* provides data persistence, version control, schema evolution and run-time application support by interpreting user demands, invoking appropriate methods and generating database operations. *SpaTemp* is a spatio-temporal data management component, that enables unified and integrated processing and management of spatial, temporal and thematic data about geographic entities [11].

*SpaTemp* represents the kernel for specific temporal GIS development and provides the software support in the application development as well as in the run-time.

GeoQA is one of the most important GiniNT components because it has a main role in communication between the end-user and GIS application. The closer this communication simulates the interaction among humans about geographic data, the use of GIS is more natural and effective, so the less time is necessary for non-expert end-users to learn how to benefit from GIS. GeoQA enables formulation and processing of both spatial and alphanumeric queries, as well as queries that combine spatial and thematic properties and conditions. GeoQA also provides performing of various spatial analysis functions (such as proximity analysis, nearest neighbour queries, buffer zone and shortest path analysis), interactive distance measure, basic statistical evaluations, storage of intensively used queries or some important query results, and graphical input and output of queries and analysis functions.

GeoQA has significant functional connections with the other GiniNT components. It uses *Object Wizard* about database schema, application definition and OO spatial data model, as well as, *Mediator* and *SDM* for spatial data browsing and indexing. It is linked with an underlying RDBMS about non-spatial query processing and uses *SpaTemp* about temporal aspects of spatial entities. Finally, GeoQA uses the graphical user interface module to provide interactive, user-friendly environment for querying and analysis as well as graphical presentation of the results.

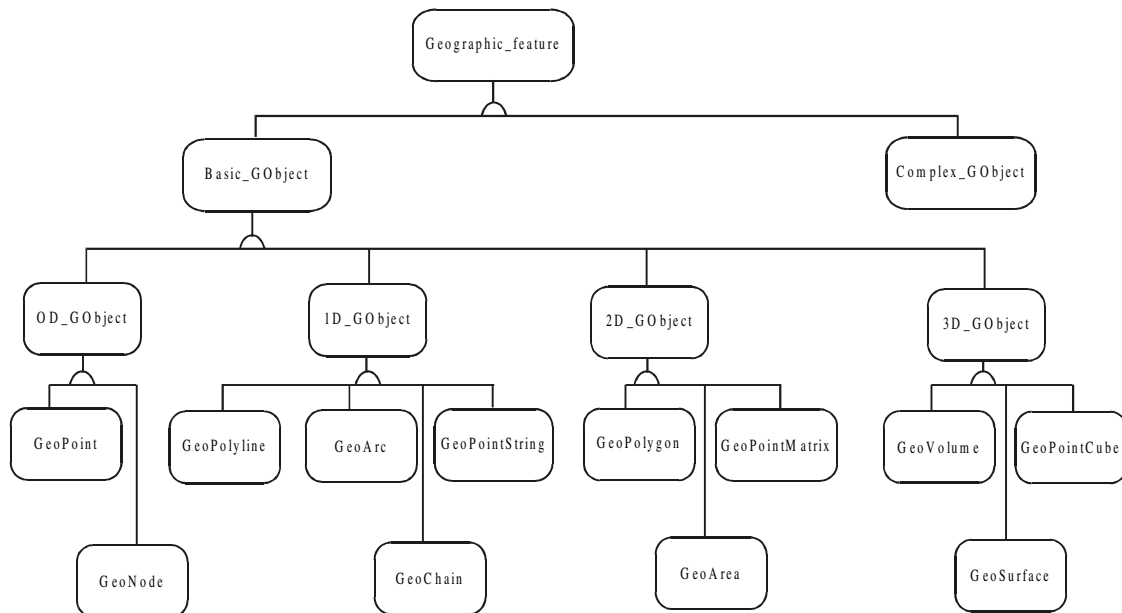
### 3. GINIANT SPATIAL MODELS

We have developed a spatial data model, as well as spatial relation model, based on the concepts commonly found in the literature. Spatial data model is a basis for specific user application development. Spatial relation model, and its implementation inside spatial data model, represent the nucleus of GeoQA and the first step in its development.

#### 3.1 Spatial data model

GiniNT data model is based on object-oriented paradigm and supports common object-oriented concepts such as objects, classes, attributes, object identity, aggregation and generalization/specialization. The model is defined in the form of a hierarchy of spatial classes representing spatial features and geometric concepts found commonly in the multidimensional geometric space [7]. Figure 2 gives a representation of the spatial feature class hierarchy.

The top-level and therefore the most abstract class of our data model is *Geographic\_Feature*. It represents a set of attributes and operations common to all instances that are stored in the geographic database. This class is specialized into two different subclasses *Basic\_GObject* and *Complex\_GObject*. Basic objects are atomic objects of the database describing a single geographic abstraction. A basic object contains a description of the geometry related to this abstraction. Based on the object geometry methods for basic operations can be provided which are useful in all GIS application areas.



**Figure 2. Geographic features class hierarchy.**

We distinguish the basic spatial objects by their dimensionality, so there are classes for zero-dimensional objects (*0D\_GObject*), one-dimensional objects (*1D\_GObject*), two-dimensional objects (*2D\_GObject*) and three-dimensional objects (*3D\_GObject*). Furthermore, the vector-based (*GeoPoint*, *GeoPolyline*, *GeoArc* and *GeoPolygon*) and raster-based representations (*GeoPointString*, *GeoPointMatrix* and *GeoPointCube*) are distinguished. Our data model integrates both spaghetti data model and topological data model, so it contains classes representing various topological concepts, such as *GeoNode*, *GeoChain*, *GeoArea* and *GeoSurface*. Complex geographic features are represented as instances of class *Complex\_GObject*, which consist of organised collection of basic geographic features.

All these classes contain a description of geometry and attributes related to corresponding spatial abstraction as well as the set of appropriate class methods representing spatial relations. Spatial feature class hierarchy is extensible, thus enabling the user to specify application specific classes with inherited geometry and related operations, and define special thematic properties and behavior of the real world entity. Model enables the user to create a GIS application by defining its object-oriented model on the base of presented data model. The user can add all concrete information required in a specific GIS application only by deriving further necessary subclasses representing the real-world entities (cities, forests, railways, rivers) from presented class hierarchy.

### 3.2 Model for spatial relations

Spatial relations existing between the geographic objects play a central role both at the query definition level and at the query processing level. It is often said that spatial queries are queries about spatial relations between objects. Models for spatial

relations have been the focus of much attention in the GIS research over the last few years [1][5]. In our work, we used the benefits of presented models, but also tried to avoid their drawbacks. Our spatial relation model consists of topological, direction and geometric relations.

Topological properties of spatial objects (disjoint, overlap, adjacent to) are the primary information which users of GIS need to deal with. A good formal approach for the definition of topological relations are models with intersections (*4-intersection* and *9-intersection*) based on the point-set theory [5]. However, we agree with Clementini [1] that the serious practical drawback of this approach is that it potentially results in too many different relations to be used by end-users. It is unsatisfactory because of the limited cognitive, intuitive and linguistic capabilities of the occasional and non-expert end-users of specific GIS application.

Our aim (as in [1]) is to formally define the set of topological relations, small as possible, which is sufficient for representing all possible topological configurations [5]. However, our set is different than the object calculus model set (*touch*, *in*, *cross*, *disjoint* and *overlap*) defined in [1]. We think that the definition of two different forms of intersection concept inside the model depending on the dimensionality of including objects (*cross* and *overlap*) can be quite ambiguous and can make a confusion to potential end-users in a real geographic situation. Furthermore, we include both *inside* and *contain* topological relations into our model. Although these relations represent two similar, but inverse topological concepts, we think that the possibility of its separate definition and referencing inside the query statement are necessary and useful. We defined five basic topological relations: *disjoint*, *meet*, *inside*, *contain* and *intersect*. These relations are mutually exclusive and cover all possible topological situations.

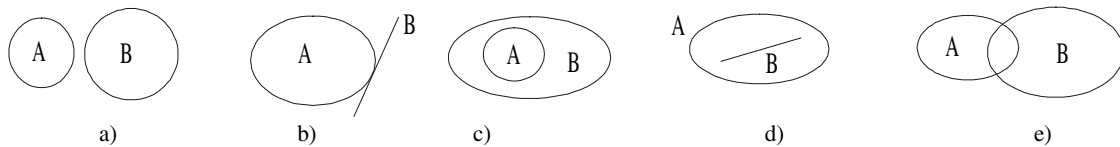


Figure 3. Five basic topological relations a) disjoint, b) meet, c) inside, d) contain, e) intersect.

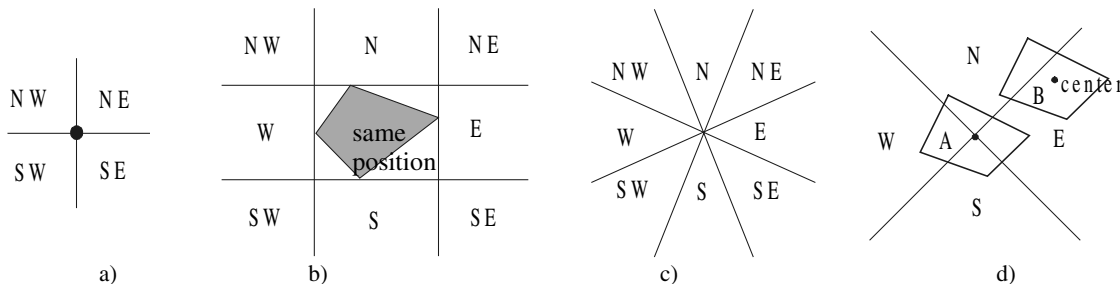


Figure 4. Models for direction relations: a) half-planes, b) projection-based, c) cone-shaped, d) B east of A.

Direction relations deal with order in space and represent a deeper step of spatial analysis. Two main approaches for the definition of direction relations are *cone-shaped* model [9] and *projection-based* model [8], Figure 4. We chose *cone-shaped* model as a basis for our direction relation model because of some drawbacks of the second model. *Projection-based* model does not enable the definition of the set exclusively consist of four primary direction relations (*north*, *south*, *east* and *west*), which is the most frequent and the most important case in real geographic situations from the ordinary end-user point of view. Projection-based model with 4 half-planes defines four but secondary direction relations (*northeast*, *northwest*, *southeast*, *southwest*), Figure 4a. Furthermore, direction relations in the projection-based model with 8 relations (4 primary relations and 4 secondary relations) do not cover equivalent parts of space; i.e. larger regions belong to secondary relations, Figure 4b.

On the other hand *cone-shaped* model provides the definition of various number (4 or 8 depends on particular needs) of equivalent relations, Figure 4c. Remaining problem is the definition of direction relation between two non-point spatial objects. The question is how to define radial lines through the reference object and how to determine direction relation of primary object with the respect to reference object when primary object can be potentially intersected by some of radial lines. In that case we use the gravity centers of the spatial objects as their point approximations to determine the direction relation between them, Figure 4d.

Geometric relations define some common metric properties of spatial objects such as *length*, *area*, *volume* and *distance*. Distance concept play a central role in proximity analysis, i.e. range queries, nearest neighbour queries and shortest path queries. Unary metric relations are defined by corresponding mathematical terms, while the distance between two spatial objects is defined according to Euclidean geometry.

### 3.3 Implementation of spatial relations

Defined spatial relations are declared and implemented as methods assigned to the classes of the spatial feature class hierarchy we presented. Dimension dependant relations (*length*, *area*, and *volume*) are declared in the classes defining spatial

objects with corresponding dimensionality. Topological and direction relations as well as distance relation are declared in class *Geographic\_Feature*, i.e. the top-level class of our hierarchy. Topological and direction relations are binary operations with the logical result, so the skeleton of their definition (in an object-oriented manner) is:

```
Boolean Top_or_Dir (Geographic_Feature featureX);
```

Distance relation is binary operation with numerical result:

```
Double Distance (Geographic_Feature featureX);
```

It is obvious that all these functions have to be redefined in the subclasses to be implemented efficiently according to the dimensionality of including objects. In the implementation of the functions we used various geometric filters, computational geometry methods and graph-theory methods such as grid-file structure, minimal bounding rectangle (MBR) object approximations, efficient intersection algorithms, *point\_in\_polygon* and *point\_on\_polyline* tests and some original geometric algorithms. We have applied all these methods in order to improve the speed and efficiency of query processing based on that implementation.

## 4. GRAPHICAL USER INTERFACE

The user interface is often the only part of a GIS with which the user has direct contact so its design is a crucial factor in the user's understanding of the capabilities of the system. GeoQA is tightly linked with the *GinisNT* graphical user interface (GUI). This GUI is based on many advanced, up-to-date visual techniques, elements and opportunities, such as *WYSIWYG*, *MDI*, icons, direct object manipulation, dialog forms, pop-up menus etc. It gives high-level graphical access to the system and provides efficient communication facilities, successful choice of desired functions, setting certain parameters and a user-friendly and effective environment for geographic database querying and analysis. Such GUI is very important especially for the occasional or non-expert users of a GIS application.

The basis of the *GinisNT* user interface is georeferenced continuous raster map displayed on a screen, Figure 5. Raster maps as background for the user interface have many advantages

such as the efficiency of the operations and ease-of-use for end-users already familiar with their paper equivalents. This base map enables users to move, pan, and zoom over it. Also, it provides users with all information necessary for their spatial referencing and locating by existing spatial objects in the presented space. The GinisNT spatial database includes the raster map database containing raster maps of different scales. Such raster maps represent a basic layer for other layers containing geographic data in a vector graphic form, as well as, specific symbols and annotations [7].

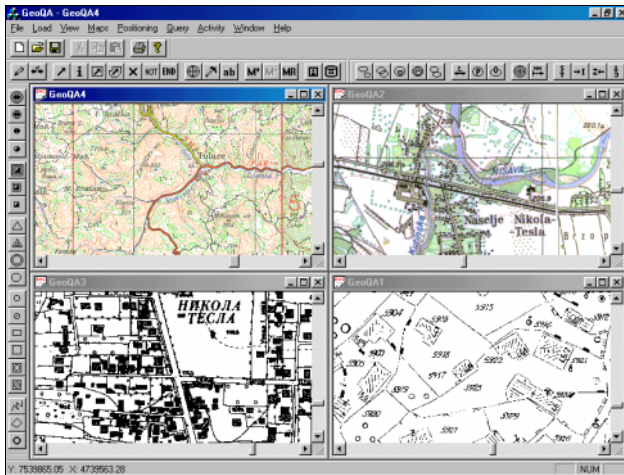


Figure 5. The GinisNT user interface.

The GinisNT user interface provides direct object manipulation using direct manipulation device - mouse. This capability is frequently used in definition of the graphical input of some spatial and non-spatial queries; i.e. it allows users to formulate queries with reference to spatial objects visible on a screen. Direct manipulation is also very significant for direct interaction between a drawn spatial entity and its thematic attributes displayed in the specific dialog forms.

GUI provides two sets of easily understandable and visually expressive icons, displayed in toolbars, Figure 5. These icons enable an interactive, visual and effective formulation of a wide range of query and analysis functions. The first set consists of icons representing all spatial entities, which are of particular interest in specific GIS application. The icons of the second set represent all available spatial relations (topological, geometric and direction) and various spatial operators such as point, window and region selection, negation of results, cancellation of results and many others.

Visual context of all presented icons is defined in accordance with the theme. Picturesqueness and expressiveness of these icons provide convenient, simple and user-friendly interaction with GIS via querying and analysis, especially for non-expert users. GUI also offers many expressive on-screen forms, message boxes and pop-up menus which lead the user through semantically correct query and analysis process and provide interactive and incremental environment for performing these activities.

## 5. QUERYING AND ANALYSIS

GeoQA provides both simple point-and-click query capabilities and sophisticated queries, analysis and display functions using visual, user-friendly techniques. GeoQA provides timely information and decision making support to GIS users. It helps users to solve problems, analyse geographic situations, extract necessary data and generate new information.

### 5.1 Spatial operations

The simplest query provided by GeoQA is *point-query* (*information query*), which essentially asks the question "What is this spatial entity" using direct manipulation. This query, i.e. referenced position on the screen can be specified by the right mouse button, due to its common role as a "property" button in the Windows environment. Another way is by using information ("i") icon from the spatial operation toolbar and after that the left mouse button for the direct selection of entities. As a result, all thematic properties of the referenced spatial entity are shown in appropriate dialog form.

The next type of query is a *region-query*, which asks the question "What entities are located in this region". This query defines a polygon in the space and requests information regarding spatial entities that are contained in, adjacent to, or overlap the polygonal area so defined. Region queries frequently provide entries for upcoming queries, especially as a method for restricting of an area of interest. GeoQA enables formulation of both the *window* queries defined by rectilinear rectangles, and the *region* queries defined by free form polygonal areas on the screen. These queries in GeoQA are specified by choosing the entity of interest from the spatial entity toolbar, then selecting the *window* (or *region*) query button from the spatial operation toolbar, and finally using mouse for drawing the region on the screen. As a result of such an activity, entities enclosed by a query region are marked by specific colour. After that, the user can perform information (i.e. *point*) queries on these entities, or use them in various ways in future querying and analysis.

### 5.2 Spatial querying and analysis

Complex spatial queries including spatial relations are formulated by combining available icons, dialog forms and text in an interactive manner. GeoQA allows two different ways for the spatial query composition. The first way is easier for use and more efficient than the other one. Spatial queries are formulated by specific GUI component, called *Query Composer*, Figure 6. Using this method, the user first selects reference objects (i.e. objects in relation to which the primary objects is located) on the screen using the selection toolbar button ("arrow" icon) and mouse clicks. After that the user activates *Query Composer* and defines a spatial query by choosing thematic types of primary and reference objects, along with corresponding spatial relation (eventually its negation) through appropriate list boxes of the dialog form, as in Figure 6.

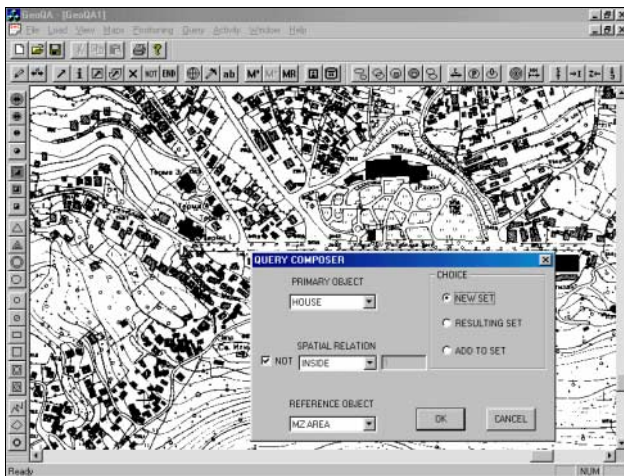


Figure 6. Spatial query formulation by Query Composer.

The second way is more visual and attractive. It represents a kind of an experiment about iconic way of query composition. Query statements are formulated by choosing icons for desired spatial entities from the spatial entity toolbar (primary and reference objects in a spatial query condition) and combining them with the icons for the necessary spatial relations from the spatial relation toolbar. After the query has been defined and before it is processed, a simple textual form of the specified spatial query is shown on the screen, so the user can test whether there are any mistakes in the query, and according to that, cancel the query.

GeoQA provides performing of the spatial join operation widely used in GIS applications for combining spatial objects of two sets according to some spatial relations. This operation can be performed without previous selection of any reference objects on a screen (no matter what method for composition is used). The query "Find all houses for sale within distance of 500 meters from a school" is an example of a spatial join.

GeoQA provides an interactive distance measure through the corresponding mouse actions. In that way the start and the end position along with all intermediate points (if distance is a polyline form) are specified using a mouse click. As the result of such activity, the distance expressed in meters is shown on a screen. GeoQA also enables performing of proximity analysis that handles various distance concepts. This analysis is expressed through the range queries, nearest neighbour queries and shortest path queries. A range query selects all spatial objects of corresponding thematic type which distances from reference object are less (or greater) than predefined threshold. A nearest neighbour query selects the specific number of spatial objects of the corresponding type closest to a given point in space (or to reference object). The shortest path query shows the shortest path between two nodes (objects) belonging to specific network structure. Proximity analysis is specially important and frequently used in the real geographic situations, where the spatial locating and distance between spatial objects are the major tasks of interest.

### 5.3 Thematic and combined querying

GeoQA provides standard alphanumeric querying through the *SQL Query Builder* component, shown in Figure 7. A thematic

query condition is defined by choosing the desired attributes of the spatial entities from the attribute listbox, their specific values from the value listbox, and combining them with various relational and logical operators represented by icons in the *Query Builder* dialog form. The defined logical term is shown in the specific text box of the dialog form, and it represents the standard SQL "WHERE" clause. The user can interactively change the query condition in the *Query Builder*, if the user notices that the term is incorrect. Also, if such an incorrect query is activated, GeoQA gives a corresponding error message, helping the user to correct existing errors.

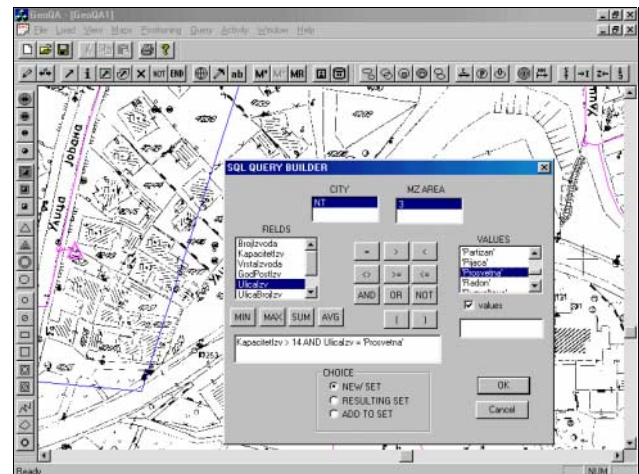


Figure 7. Alphanumeric query formulation.

GeoQA provides basic statistical analysis through the set of aggregate operators: minimum, maximum, sum and average. These operators are available as icons inside the *Query Builder* dialog form. They can be applied on the set of specific attribute values as a support for thematic querying and analysis. This set of operators can be easily extended by adding of the advanced statistical functions depending on particular needs.

Spatial and non-spatial queries can be combined in some complex query sequences, where the logical operators (AND, OR) are simulated by a specific mechanism. For example, a current query can refer only to the resulting entities of preliminary query activities and perform its selection on that set (AND operation) or add its results to those entities (OR operation). Also, resulting entities of one query can be used as reference objects in an upcoming spatial query enabling interactive and incremental environment for query processing. In this manner, various mixed multicriteria queries can be specified, for example: "What houses for sale with more than 3 bedrooms meet the Green park, west of the Karl's bridge".

After a spatial or thematic query has been defined, GeoQA provides fast and effective query processing. It uses various geometric filters, spatial indexing (grid structure) and computational geometry algorithms for spatial query processing and underlying RDBMS and *Mediator* for non-spatial query processing [7]. Query results are displayed in a graphical form on a raster map using different colours, symbols and other graphic facilities, which depends on specific situations. In order to improve the understanding and analysis of the results, the area

which contains resulting spatial entities can be zoomed in and panned. Background raster maps help in spatial referencing and locating resulting spatial objects.

### 5.4 Storage Mechanism

A very important GeoQA property is the storage of the intensively used or essential queries (spatial or non-spatial, simple or complex). Such stored queries can be activated later on, when it is necessary, without need to repeat their formulation. Query storage is performed by M<sup>+</sup> and M<sup>-</sup> toolbar buttons, representing the start (when the user entitles that query statement) and the end of a procedure respectively. The previously stored queries can be activated through the *Query Memory* dialog form (Figure 8), where the user can choose the desired query by its unique name and its simple text description. This GeoQA mechanism is very convenient, especially in some stereotypic situations, when the same query must be frequently repeated.

The storage of some important query results is another important GeoQA capability. These stored resulting entities can be combined by the intersection or union set operations with the current results displayed on the screen. This mechanism provides more effective and interactive querying, where the user can link and combine several query conditions and statements in many different ways, depending on user's needs and spatial analysis goals. Presented storage capabilities result in more productive and efficient query process and spatial analysis of the specific geographic space and data.

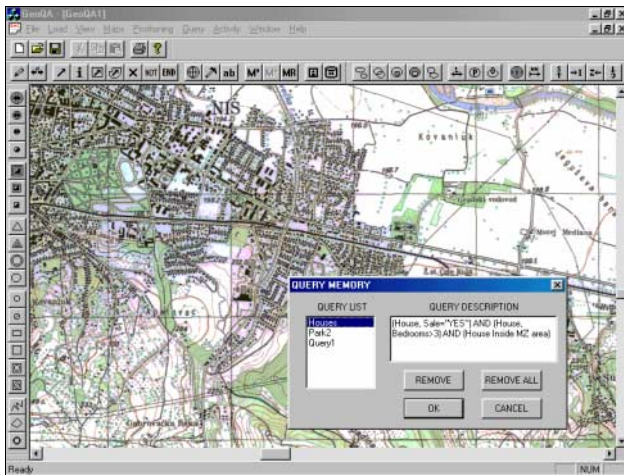


Figure 8. Stored query activation.

## 6. GEOQA IN THE TELECOM GIS

The GeoQA tool can be easily and successfully applied in a number of GIS applications that have already been developed on the top of the GiniNT framework, one of which is the GeoTT system [2]. GeoTT is a specialised GIS for inventoring, maintaining, analysing and monitoring of the TelegraphTelephone (TT) cable network. It has been developed by Computer Graphics and GIS Laboratory at the Faculty of Electronic Engineering, University of Nis, Yugoslavia for the needs of the Telecom Serbia, postal services of the Republic of Serbia, Yugoslavia. GeoTT is based on up-to-date scientific achievements in the databases and GIS technology, Figure 9.

The basis of the GeoTT system is the telecom network spatial database that contains various kinds of data in various formats:

- ♦ Raster, georeferenced maps of the TT network area at scales: 1:300000, 1:25000, 1:5000, 1:1000;
- ♦ Spatial information along with non-spatial thematic attributes fully describing telecom cable network with appropriate cable equipment: telephone exchanges, cable segments, cable conduits, junctions, junction boxes, manholes, connection boxes, terminal blocks and so on;
- ♦ Subscribers' information including their names, addresses, telephone numbers, etc;
- ♦ Multimedia data including photos, video and audio records of the TT cable network, manuals for network maintenance, warnings and critical actions;
- ♦ Information about faults and corrections on TT network;
- ♦ Spatial and thematic data about geographic entities which are important for the TT network maintenance and monitoring such as streets, rivers, buildings, drainage, etc;

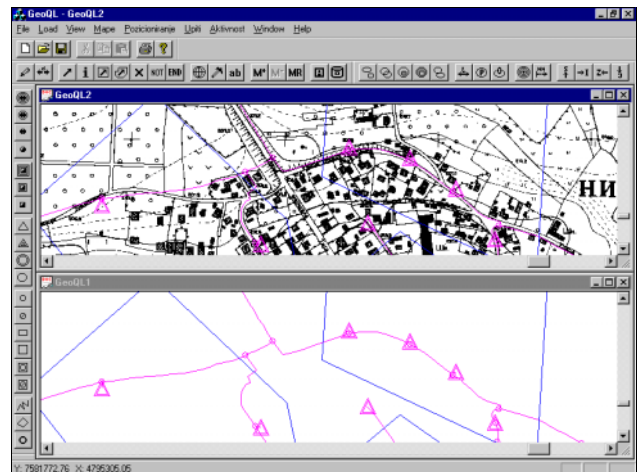


Figure 9. TT network map with (top) or without (bottom) background map.

GeoQA in the GeoTT system has shown an excellent functional performance and has helped in following activities [12]:

- ♦ maintenance, retrieval, analysis and displaying local TT network data,
- ♦ accurate and up-to-date recording and documentation of network data,
- ♦ faster and optimised network planning and design using up-to-date spatially referenced data, information on spare capacities, etc.,
- ♦ timely change management and re-engineering,
- ♦ efficient fault management and worksheet generation through the availability of the spatial information; the path operator enables determination of location of faults, bottlenecks and weak parts of the TT network with the accuracy of 25-30 cm.
- ♦ improved customer care (faster connection of new subscribers, faster fault clearance, map-supported helpdesk etc.),
- ♦ efficient queries on spare capacities, i.e. identification of free copper pairs, free fibers and free tubes,
- ♦ statistical report production,
- ♦ user's requirement processing.

It is shown that many tasks in telecom network management previously carried out manually are more effectively and easily

performed using GeoQA. GeoQA is cost effective, helps users to solve problems, make decisions and improve productivity. The most important is that it provides the telecom operator to perform TT network analysis without being a GIS expert.

## 7. CONCLUSION

GIS has become an essential tool for improving the understanding of our world. It is widely used in various application domains like utility management, urban planning, natural resource management, weather modelling, vehicle navigation, prevention of pollution and natural disasters, etc. One of the most important GIS components is its spatial query and analysis tool. This tool provides an efficient communication between the user and a GIS application in order to extract or generate new spatial information.

This paper presents GeoQA – spatial query and analysis tool for GIS applications. GeoQA has been implemented as an integral part of the GINISNT object-oriented GIS framework. It provides an effective maintenance and management of the geographic data through querying and spatial analysis of specific geographic space and joined spatial entities. The basis of the GeoQA development is definition of spatial data model, formalization of the spatial relations and their optimized implementation inside the data model. GeoQA has a powerful visual context and in interaction with GUI elements provides efficient, interactive and user-friendly environment for query composition. GeoQA enables fast query processing, graphical presentation of query results and powerful set of spatial analysis functions. Although Egenhofer's requirements for spatial query languages described in [4] only make sense in the context of graphical user interface, we think that our GeoQA tool meets all these requirements but also provides many additional sophisticated capabilities.

Further directions of our activities include the implementation of new advanced GUI elements and techniques as well as incorporating new user-defined spatial relations into the query language. We plan to incorporate qualitative spatial reasoning mechanisms into GeoQA query processor and thus to achieve the intelligent tool. Furthermore, we plan to extend GeoQA with temporal concepts and relations and thus to develop spatio-temporal query and analysis tool. GeoQA can be effectively applied in the other specific GIS applications developed on top of the GINISNT framework, such as hail suppression information system, fire department C3I system and tourist information system.

## 8. REFERENCES

- [1] Clementini, E., Di Felice, P., van Oosterom, P. A Small Set of Formal Topological Relationships for End-User Interaction. *Advances in Spatial Databases - Third International Symposium, SSD'93, LNCS 692*, pp. 277-295, Springer-Verlag, Singapore (1993).
- [2] Djordjevic-Kajan, S. Functions and Contents of Digital Maps in Process of Building GIS in Serbia PTT, in *Proc. GIS/LIS*, Budapest, Hungary, Jun 10-14, 1996, GIS/LIS Editions, 82-91.
- [3] Egenhofer, M. Interaction with Geographic Information Systems via Spatial Queries. *Journal of Visual Language and Computing*, 1, 1990, 389-413.
- [4] Egenhofer, M. Spatial SQL: A Query and Presentation Language. *IEEE Transactions on Knowledge and Data Engineering*, 6(1), Feb. 1994, pp. 86-95.
- [5] Egenhofer, M., Sharma, J., Mark, D. A Critical Comparison of the 4-Intersection and 9-Intersection Models for Spatial Relations: Formal Analysis. *Autocarto 11*, Minneapolis, MN, 1993, pp. 1-11.
- [6] Goodchild, M.F. Geographical Information Science. *International Journal of Geographical Information Systems*, 6(1), 1992, 31-45.
- [7] Mitrovic, A., Mitrovic, D., Djordjevic-Kajan S., Petkovic, M. A scaleable object-oriented GIS framework. *Workshop on New Development in GIS*, Milan, Italy, March 6-8, 1996, 20-21.
- [8] Papadias D., Sellis T. The Qualitative Representation of Spatial Knowledge in two-dimensional Space. *VLDB Journal, Special Issue on Spatial Databases*, 3(4), 1994, pp. 479-516.
- [9] Peuquet, D., Zhan, C.X. An Algorithm to Determine the Directional Relationship Between Arbitrarily-Shaped Polygons in the Plane. *Pattern Recognition* 20(1), 1987, pp. 65-74.
- [10] Stoimenov, L., Mitrovic, A., Mitrovic, D., Djordjevic-Kajan S. Bridging objects and relations: a mediator for an OO front-end to RDBMSs. *Information and Software Technology* 41 (2) (1999), pp. 57-66.
- [11] Stojanovic, D., Djordjevic-Kajan, S., Stojanovic, Z. Spatio-Temporal Data Management System: a Kernel for Temporal GIS Applications. *IASTED Applied Informatics '99 Conference*, 15-18.2.1999. Innsbruck, Austria.
- [12] Stojanovic, Z., Djordjevic-Kajan, S., Stojanovic, D. Query Language in Telecom GIS. *GISPLaNET'98 Conference*, 7-11.9. 1998, Lisbon, Portugal.